# Consumption of Black Cutworms, *Agrotis ipsilon* (Lepidoptera: Noctuidae), and Alternative Prey by Common Golf Course Predators

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# Consumption of Black Cutworms, *Agrotis ipsilon* (Lepidoptera: Noctuidae), and Alternative Prey by Common Golf Course Predators

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**ABSTRACT**   Turfgrass ecosystems contain a variety of generalist predators that may contribute to the regulation of pest insect populations. The black cutworm, *Agrotis ipsilon* (Hufnagel) (Lepidoptera: Noctuidae), is frequently a pest of short-mown golf course greens and fairways and may be a candidate for management by conservation biological control tactics. However, little is known about the susceptibility of different instar *A. ipsilon* to the many species of carabids, staphylinids, and spiders that inhabit greens, fairways, and roughs. These ecosystems also contain nonpest arthropods that could serve as alternative prey for generalist predators and help bolster their populations. In these laboratory experiments, 12 species of predators, commonly found on golf courses, were evaluated for their ability to consume five different instars of *A. ipsilon* and for their feeding voracity. The palatability of five potential alternative prey items, to a subset of predators, was also tested. All predator species tested were able to consume at least one instar of *A. ipsilon*. Two of the most common predators found on golf courses, *Amara impuncticollis* (Say) (Coleoptera: Carabidae) and Philonthus sp. (Coleoptera: Staphylinidae), could consume all *A. ipsilon* instars and were also among the most voracious predators tested. In addition, all five alternative prey items were readily eaten by the predator species that were tested. These results suggest that these generalist predators play a role in the regulation of *A. ipsilon* larval populations on golf courses and that several nonpest arthropod taxa could contribute to attracting and maintaining predator populations.

**KEY WORDS**   biological control, Carabidae, Staphylinidae, turfgrass, voracity

Turfgrass ecosystems are endowed with a variety of arthropods representing various functional groups. Of interest to pest management, and particularly conservation biological control, are predacious arthropods that may influence insect pest populations and arthropods that may serve as alternative prey items for these predators. Habitat manipulations, such as increasing mowing height (Smitley et al. 1998, Rothwell and Smitley 1999) or adding conservation strips (Frank 2003), can increase the abundance of predators and alternative prey in golf course fairways. However, in addition to enhancing their abundance, it is important to know whether the predator species influenced by these manipulations are capable of consuming key golf course pests. It is also important, if alternative prey are to attract and retain predators, that the alternative prey are palatable to these predators.

The most common predacious arthropods in turfgrass ecosystems are generalist predators such as carabid beetles, staphylinid beetles, and spiders (Cockfield and Potter 1984a, Terry et al. 1993, Smitley et al. 1998, Jo and Smitley 2003). Although carabids, staphylinids, and spiders are often lumped together as predators or natural enemies in agricultural and turf research, this is not always the case. Carabid and staphylinid beetles in particular, while members of predominantly predacious families, are often omnivores that consume seeds (Best and Beegle 1977a, Hagley et al. 1982, Barney and Pass 1986, Sunderland et al.1995) or fungus (Sunderland 1975, Dennis et al. 1990, 1991), rather than strict predators capable of reducing pest insect populations. Therefore, in the experimental system of interest (e.g., turf, corn), it is important to determine whether the most common members of these predacious families are actually capable of killing and consuming key pests.

Black cutworm, *Agrotis ipsilon* (Hufnagel) (Lepidoptera: Noctuidae), is a common pest of golf course greens and fairways. *A. ipsilon* larvae create small burrows in the thatch and soil of these areas and damage short mowed turf by chewing paths of turf in proximity to their burrows. The burrows and paths are unsightly and create an uneven playing surface. *A. ipsilon* and other noctuid pests that occur in agriculture and turf have been readily consumed by carabids and staphylinids in laboratory feeding trials

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(Frank 1971; Best and Beegle 1977a,b; Clark et al.1994). However, most of the research regarding the predation of these pests has been conducted in agricultural systems.

Laboratory feeding trials of predators collected from turfgrass systems have found carabids and staphylinids to consume a variety of turfgrass pests including sod webworm, *Crambus* and *Pediasia* spp. (Lepidoptera: Pyralidae) eggs (Cockfield and Potter 1984b), Japanese beetle, *Popillia japonica* (Newman) (Coleoptera: Scarabaeidae) eggs and larvae (Terry et al. 1993), and *Ataenius spretulus* (Haldeman) (Coleoptera: Scarabaeidae) eggs and larvae (Jo and Smitley 2003). While black cutworms or other noctuids have been used as prey items in evaluations of field predation pressure (Terry et al. 1993, Kunkel et al. 1999, López and Potter 2000, Braman et al. 2002), the palatability and susceptibility of this key golf course pest to predators have not received a comprehensive laboratory evaluation.

In addition to feeding on pest insects, generalist predators also feed on other arthropods (alternative prey) present in the turfgrass habitat. Collembola, crickets, and various heteropterans are some of the potential alternative prey items found on golf courses (Kunkel et al. 1999, Frank 2003). Large numbers of predatory arthropods may be attracted to and enticed to stay in areas with abundant alternative prey (Robertson et al. 1994, Settle et al.1996, Shrewsbury 1996, Symondson et al. 2002). In addition, the quantity and quality of available nonpest prey items may influence predators' ability to reduce pest insect populations (Symondson et al. 2002). The role of alternative prey in turf predator-pest dynamics and the palatability of these prey items are mostly unexplored.

The objective of this study was to evaluate, through laboratory feeding trials, 12 arthropod predators representing four families in two orders for their ability to consume live black cutworm larvae and pupae. In addition, five alternative prey items were evaluated for their value as alternative prey for these predators. Predators and alternative prey used in these studies are commonly found on Maryland golf courses (Frank 2003). Especially unique to these studies is that predators from turfgrass were evaluated across several life stages of the black cutworm. Often, research of this kind has focused on eggs, pupae, or first instars, the most defenseless and immobile stages, of most pests. The ability of predators to kill active and inactive stages of pests and to consume alternative prey is important in understanding the potential impact that natural enemies may have on pest populations. In addition, increased knowledge of which predator species are most voracious and which alternative prey items are palatable will allow more informed interpretation of pitfall trap and other population surveys. These studies will assist in more accurately assessing the efficacy of generalist predators as biological control agents in golf courses and other agroecosystems.

## Materials and Methods

**Collection and Maintenance of Predators and Prey.** Adult beetles and spiders used in the feeding trials were caught using dry pitfall traps, with the exception of the *Hippodamia convergens* (Guérin-Menéville) (Coleoptera: Coccinellidae) that were caught by hand on grass or flowers. All trapping was done at the University of Maryland Turfgrass Research Facility (College Park, MD). The different species were compared with a reference collection established from pitfall trapping on golf courses (Frank 2003) to confirm the same species of arthropods caught on the golf courses were tested in the laboratory feeding trials. Voucher specimens have been deposited in the Entomology Museum at the University of Maryland.

Collection of predators began in April 2003 and continued, as needed, through July 2003, when all feeding trials were completed. Carabid and staphylinid beetles were retained in the laboratory in shallow plastic bins containing moist potting soil. They were fed cat food (Purina Cat Chow, St. Louis, MO) and kept at room temperature. Spiders were kept individually in glass jars containing moist potting soil and fed black cutworm larvae and other small arthropods. *H. convergens* were housed in a closed plastic container and provided with water and a sugar-water solution. New individuals of all taxa were continuously trapped and added to the colonies to replace ones that died and to ensure healthy predators were available for the feeding trials. Only adult predators were used in these experiments. Black cutworms were reared by Dow Agrosciences (Indianapolis, IN). Cutworms were maintained on artificial diet and stored in a growth chamber at 16°C until needed.

**Consumption of *A. ipsilon* Larvae and Pupae by Predators.** The families, genera, and species of predators evaluated in the feeding trials were Carabidae: *Scarites substriatus* (Haldeman), *Pterostichus lucublandus* (Say), *Amara impuncticollis* (Say), *Stenolophus lecontei* (F.), *Stenolophus ochropezus* (Say), *Bembidion* sp.; Staphylinidae: *Philonthus* sp., *Tachinus canadensis* (Horn), *Aleochara* sp., *Meronera* sp.; Coccinellidae: *Hippodamia convergens*; Lycosidae: *Pardosa* sp.

Feeding trials used first, third, fifth, and seventh instars and pupae of *A. ipsilon* as prey. All 12 predator taxa were used in the first instar trials. If fewer than 30% of a predator species consumed larvae of a given instar, then that species was not used in trials of the next larger *A. ipsilon* instar. All available taxa were used in trials with pupae because pupae are immobile and even small predators may have been capable of consuming them. The number of replicates for each predator species varied because of limited availability of some field populations. Twenty replicates of each species were conducted in trials with first instars, except for *S. substriatus*, for which 10 replicates were conducted. In trials with third instars, *S. substriatus* and *P. lucublandus*, 10 replicates were conducted, while all others had 20. All species in fifth and seventh instar trials had 10 replicates, except *A. impuncticollis*, which had 20. *Philonthus* sp., *A. impuncticollis*, and

*S. lecontei* had 20 replicates in pupae trials, while all others had 10.

All predators were starved in individual 9-cm-diameter petri dishes with moist filter paper for 24 h before the trials. Starvation and the subsequent feeding trials took place in growth chambers at 25°C under a photo period of 16:8 h (light:dark). Feeding trials were conducted during the dark phase. After starvation, one cutworm of the appropriate instar was added to each dish. Petri dishes were returned to the growth chamber and then checked every hour for 5 h, at which time cutworms were recorded as either eaten or not eaten. If cutworms were partially consumed, they were scored as eaten.

**Statistical Analysis.** The number of predators in each species that consumed *A. ipsilon* larvae in the feeding trials was compared within each instar. A contingency table was constructed for each instar. Contingency tables were analyzed using $\chi^2$ in the FREQ procedure of SAS 8.2 (SAS Institute 2001). Fisher exact test was used when analyzing the fifth instar, seventh instar, and pupae tables because of many cells containing low values. When the $\chi^2$ statistic was significant for a given instar, $2 \times 2$ contingency tables were constructed to compare each predator species with every other predator species within that instar using $\chi^2$ with Fisher exact test (SAS Institute 2001).

**Voracity of Predators.** A voracity score was created to facilitate comparisons of how readily predators consumed *A. ipsilon* larvae. The voracity score combined data on how many predators of each species consumed cutworms with how quickly they were consumed. Each individual predator was given a voracity score based on the time at which they consumed the larvae during the feeding trials. The voracity score equals the number of larvae eaten (0 or 1) by the individual predator divided by the hour (1–5) in which the larva was eaten. For example, predators that consumed the larva in the first hour of the trial received a score of $1/1 = 1$, whereas a predator that consumed the larva in the fifth hour received a voracity score of one-fifths = 0.2. Predators that did not consume the larva received a score of 0.

**Statistical Analysis.** Analysis of variance (ANOVA) was performed on predator voracity scores using PROC MIXED (SAS Institute 2001) to compare the mean voracity score for each predator species within each cutworm instar. Pairwise (least significant difference (LSD)) comparisons between predator species within each instar were conducted using LSMEANS with the PDIFF option in the MIXED procedure (SAS Institute 2001).

**Feeding Rate of Predators.** *P. lucublandus*, *A. impuncticollis*, and *Philonthus* sp. were evaluated to determine how many *A. ipsilon* larvae these predators would consume in 6 h. Ten individuals of each predator species were starved for 24 h in 9-cm-diameter petri dishes, as described for the feeding trials. After 24 h, 2 first instar *A. ipsilon* were placed in each dish. Every hour for 6 h, the dishes were examined, larvae

counted, and missing larvae were replaced. Therefore, each beetle could have a maximum feeding rate of 14 *A. ipsilon* larvae (2 initially + 2 per hour for 6 h), but no more than 2 larvae were present at a time.

**Statistical Analysis.** Feeding rate data were analyzed using PROC MIXED (SAS Institute 2001) to compare the mean larvae consumed by the 10 beetles in each species. Pairwise (LSD) comparisons between predator species were conducted using LSMEANS with the PDIFF option in the MIXED procedure (SAS Institute 2001).

**Consumption of Alternative Prey by Predators.** Nonpest arthropods that are found in golf course turf (Frank 2003) were evaluated as potential alternative prey items for six of the predators evaluated in the *A. ipsilon* feeding trials. Five alternative prey items were used in this experiment: collembola (Collembola: Entomobryidae), crickets (Orthoptera: Gryllidae), grasshoppers (Orthoptera: Acrididae), isopods (Isopoda), and froghoppers (Heteroptera: Cercropidae). Prey items were caught the day of the trial using a D-Vac (Rincon-Vitova Insectaries, Ventura, CA) insect vacuum.

The size of the individual prey items used in the trials was kept consistent within each prey type, but not necessarily between prey types. For instance, all crickets used in the trials were 4–6 mm in length, but this is considerably larger than the collembola that were 2 mm. Isopods were 3–5 mm, grasshoppers were 7–9 mm, and cercropids were 3–4 mm. Initial trials with live prey indicated that the predators had a difficult time catching active prey such as crickets or grasshoppers in the empty petri dishes. Collembola and cercropids, however, would rest on the lid of the dish, where they were inaccessible to the predators. Therefore, freshly frozen (dead) prey individuals were used in all alternative prey feeding trials. Alternative prey trials were carried out, as described for the cutworm consumption trials. Ten replicates of each predator were conducted for each prey type. Six predator species were used in the collembola trials: *S. substriatus*, *P. lucublandus*, *S. lecontei*, *Bembidion* sp., *A. impuncticollis*, and *Philonthus* sp. Only *P. lucublandus*, *S. lecontei*, *A. impuncticollis*, and *Philonthus* sp. were used in the other alternative prey trials because of limited availability of the other species.

**Statistical Analysis.** The number of beetles in each predator species that consumed the alternative prey items was compared within each prey type. A contingency table was constructed for each prey type and for each predator species. Contingency tables were analyzed using $\chi^2$ with Fisher exact test in the FREQ procedure of SAS 8.2 (SAS Institute 2001).

## Results

**Consumption of *A. ipsilon* Larvae and Pupae by Predators.** All of the predator taxa used in this trial consumed *A. ipsilon* larvae or pupae (Table 1). The proportion of individuals that consumed *A. ipsilon* larvae differed significantly between predator species for first ($\chi^2 = 93.8$, df = 11, $P < 0.0001$), third ($\chi^2 = $

**Table 1. Proportion of predator individuals that consumed black cutworms of various instars in petri dish feeding trials**

| Predator | Predator size (mm) | Black cutworm instar | | | | |
|---|---|---|---|---|---|---|
| | | 1st | 3rd | 5th | 7th | Pupae |
| Carabidae | | | | | | |
| Scarites substriatus | 24 | 0.3ef | 1.0a | 1.0a | 0.9a | 1.0a |
| Pterostichus lucublandus | 13 | 0.7bcd | 1.0a | 1.0a | 0.3b | 0.9ab |
| Amara impuncticollis | 8 | 0.8abc | 0.45b | 0.2b | | 0.6b |
| Stenolophus lecontei | 7 | 0.6cde | 0.35bc | | | 0.25c |
| Stenolophus ochropezus | 7 | 0.35ef | 0.1cd | | | 0.0c |
| Bembidion sp. | 4 | 0.5de | 0.0d | | | |
| Staphylinidae | | | | | | |
| Philonthus sp. | 11 | 1.0a | 0.9a | 0.4b | 0.1b | 0.55b |
| Tachinus canadensis | 4 | 0.1f | | | | |
| Aleochara sp. | 3 | 0.7bcd | 0.0d | | | |
| Meronera sp. | 3 | 0.05f | | | | |
| Coccinellidae | | | | | | |
| Hippodamia convergens | 6 | 0.9ab | 0.35bc | | | |
| Lycosidae | | | | | | |
| Pardosa sp. | 6 | 1.0a | 0.55b | 0.3b | 0.1b | 0.0c |

Proportions compared using $2 \times 2$ contingency tables across species for each cutworm instar. Proportions with the same letter, within a column, are not significantly different at the $P < 0.05$ level. Species without a value were not tested for that instar.

86.7, df = 9, $P < 0.0001$), fifth ($\chi^2 = 29.2$, df = 4, $P < 0.0001$), and seventh ($\chi^2 = 18.9$, df = 3, $P < 0.0001$) instars and for pupae ($\chi^2 = 42.2$, df = 6, $P < 0.0001$) (Table 1).

*S. substriatus* and *P. lucublandus* had the highest proportion of beetles that consumed *A. ipsilon* larvae of every instar, except for the first instar. In trials using first instars, all *Philonthus* sp. and *Pardosa* sp. consumed the larvae. Two smaller staphylinids, *T. canadensis* and *Meronera* sp., had the lowest (0.1 and 0.05, respectively) proportion of beetles that consumed first instars. The proportion of *Bembidion* sp. and *Aleochara* sp. individuals that consumed first instars was 0.5 and 0.7, respectively. However, none of the beetles from these species consumed third instars. A proportion of *Pardosa* sp. consumed every instar of larvae, but no *Pardosa* sp. consumed pupae.

**Voracity of Predators.** The voracity scores of predator species were significantly different for first ($F = 14.68$; df = 11, 208; $P < 0.0001$), third ($F = 21.41$; df = 9, 160; $P < 0.0001$), fifth ($F = 46.25$; df = 4, 65; $P < 0.0001$), and seventh ($F = 16.43$; df = 3, 36; $P < 0.0001$) instar larvae and pupae ($F = 17.68$; df = 6, 93; $P < 0.0001$) (Fig. 1, A–E). Overall, *S. substriatus* and *P. lucublandus* were the most voracious predators of *A. ipsilon* larvae and pupa.

**Feeding Rate of Predators.** Predators consumed significantly different numbers of cutworm larvae within the 6-h period ($F = 17.56$; df = 2, 27; $P < 0.0001$). The staphylinid *Philonthus* sp. and the carabid *A. impuncticollis* consumed an average ($\pm$SE) of $7.1 \pm 0.76$ and $7.2 \pm 0.64$ first instars, respectively, in 6 h. Both consumed significantly less (LSD, $P < 0.05$) than *P. lucublandus* beetles, which consumed an average of $11.5 \pm 0.26$ first instars in 6 h.

**Consumption of Alternative Prey by Predators.** In general, all of the predator species readily consumed all five alternative prey types (Table 2). All 10 *P. lucublandus* consumed every type of prey item, except the cercropids. When comparing the proportion of all predator species that consumed each prey

type, there were significant differences between predator species for collembola ($\chi^2 = 23.7$, df = 5, $P < 0.05$), cricket ($\chi^2 = 6.2$, df = 3, $P < 0.05$), isopod ($\chi^2 = 6.1$, df = 3, $P < 0.05$), grasshopper ($\chi^2 = 2.5$, df = 3, $P < 0.05$), and cercropid ($\chi^2 = 2.7$, df = 3, $P < 0.05$) (Table 2).

**Discussion**

While the consumption of prey items in laboratory studies does not necessarily reflect a predator species' natural feeding tendencies, it does demonstrate the ability of a species to consume prey, the palatability of that prey, and the potential voracity of predator species. Every predator species tested in this experiment consumed at least one life stage of *A. ipsilon* larvae. From a biological control perspective, this is encouraging.

The ability of predators to consume cutworms in this experiment appeared to vary with the size of the predator and the size of the cutworms. As would be expected, larger beetles usually consumed more cutworms and larger cutworms than smaller beetles. However, while size is important, it is not the only characteristic governing predator consumption and voracity. The small staphylinid beetles, *T. canadensis* and *Meronera* sp., were either incapable of consuming even first instars (2 mm) or perhaps did not find them acceptable to eat, as only one beetle of each species consumed a cutworm. However, *Bembidion* sp. and *Aleochara* sp. beetles, which are similar in size to *T. canadensis* and *Meronera* sp., consumed relatively high proportions of first instars. The largest beetle, *S. substriatus* (24 mm), may have had difficulty detecting the small first instars, as only 3 of the 10 tested consumed first instars, while they consumed high proportions of every larger instar. Similarly, a smaller proportion of *P. lucublandus* (13 mm) consumed first instars than consumed third or fifth instars. A similar result was found for *Pterostichus melanarius* (Illiger) by Hagley et al. (1982) when only 33% of these large
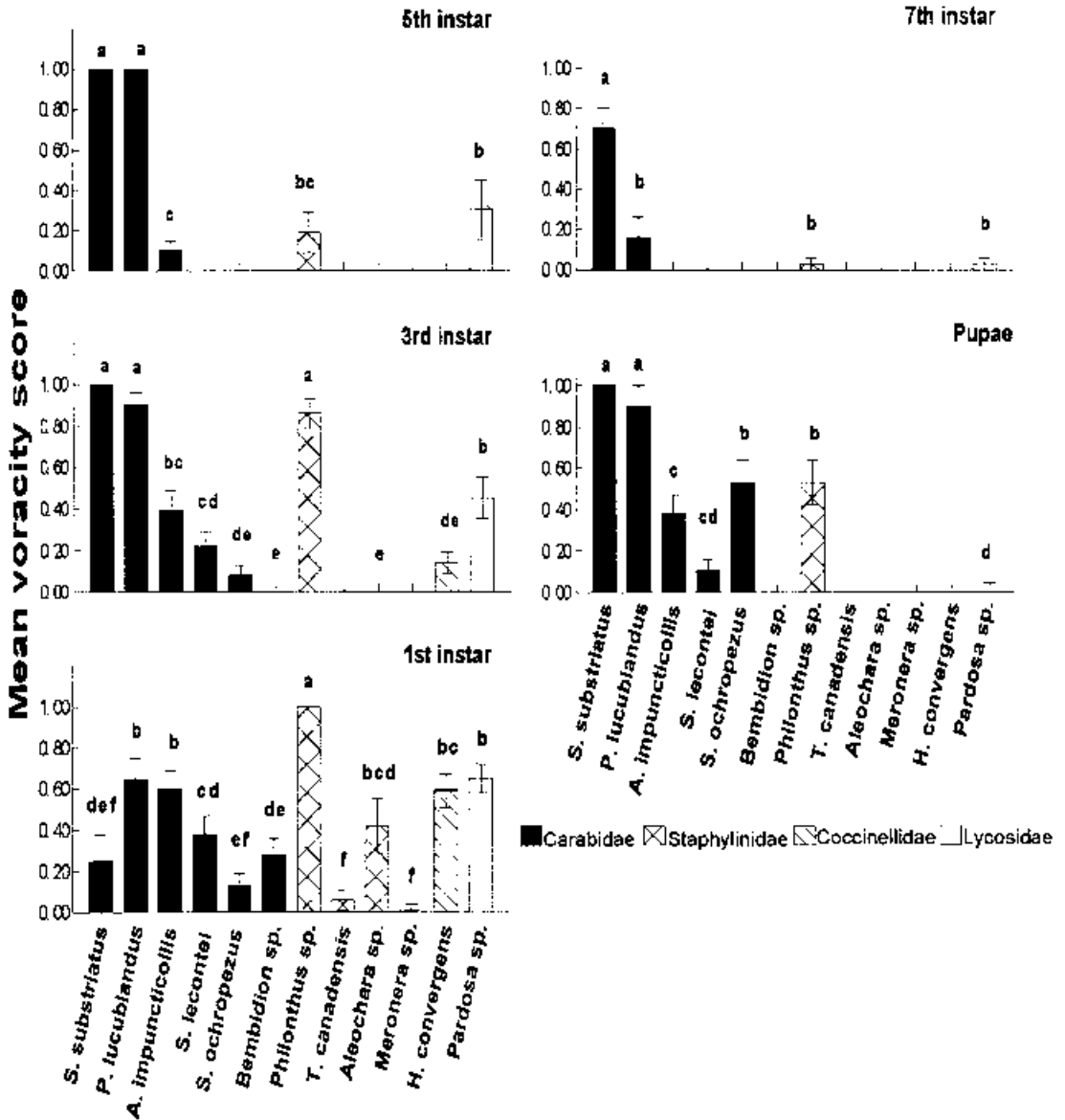
**Fig. 1.** Mean voracity score of the 12 predator species tested in feeding trials with five instars of *A. ipsilon*. Voracity scores range from 0 to 1. A score of 1 indicates that all beetles consumed the larva in the first hour of the test. Bars with different letters within an instar are significantly different at *P* < 0.05 level (LSD test). Species without a rank letter were not tested with that instar.

beetles ate first instar codling moths, but ate considerably more of the larger instars. In field predation experiments on golf courses, López and Potter (2000) found that first instar *A. ipsilon* were more vulnerable to predacious ants than third and fourth instars. However, third instar vulnerability also varied by predator species (López and Potter 2000).

Extensive pitfall trapping found *Amara* spp., *Philonthus* spp., and spiders to be very abundant predators on Maryland golf courses (Frank 2003), which is consistent with similar studies on golf course turf in Michigan (Rothwell and Smitley 1999, Jo and Smitley 2003).

In feeding trials, *A. impuncticollis* and *Philonthus* sp. were observed attacking larvae larger than themselves repeatedly, but seemed mechanically limited in their ability to kill these larvae, rather than unwilling (S. Frank, personal observation). These predators also had very high voracity scores in this study. Predators such as these that are abundant, voracious, and can consume a wide range *A. ipsilon* instars may prove an especially important force in regulating pest populations.

All of the predator species used in these experiments are found on Maryland golf courses. However,

**Table 2. Proportion of each predator species that consumed different potential alternative prey items**

| | Alternative prey type | | | | |
| --- | --- | --- | --- | --- | --- |
| | Collembola | Cricket | Isopod | Grasshopper | Cercropid |
| Carabidae | | | | | |
| *Pterostichus lucublandus* | 1.0a | 1.0a | 1.0a | 1.0a | 0.9a |
| *Amara impuncticollis* | 1.0a | 1.0a | 0.9ab | 0.9a | 0.8a |
| *Stenolophus lecontei* | 0.4b | 0.7a | 0.6b | 0.8a | 0.6a |
| *Bembidion* sp. | 0.9a | | | | |
| Staphylinidae | | | | | |
| *Philonthus* sp. | 1.0a | 0.8a | 0.8ab | 0.8a | 0.8a |
| *Tachinus canadensis* | 0.9a | | | | |

Ten replicates were conducted for each predator/prey combination. Proportions compared using $2 \times 2$ contingency tables across species for each alternative prey type. Proportions with the same letter (within a column) are not significantly different at the $P < 0.05$ level. Species without a value were not tested for that prey type.

some species such as *S. substriatus* and *P. lucublandus* are more commonly found in complex habitats, such as near the edge of woods or naturalized areas of golf courses, than in the fairways or roughs (S. Frank, personal observation). *S. substriatus* and *P. lucublandus* were included in these experiments because it may be possible to attract these predators into fairways by implementing conservation biological control practices. These species in particular are large predators that were quite voracious in the feeding trials, suggesting they would be of benefit if they could be attracted into pest-prone fairways. Several studies have demonstrated that it is possible to manipulate managed habitats and enhance predator abundance (reviewed by Gurr et al. 2000 and Landis et al. 2000). Moreover, habitat manipulations have increased the abundance of some of the same or related predators used in these feeding trials. For example, adding conservation refuges increased carabid and other generalist predator abundance in golf course turf (Frank 2003) and agricultural fields (Thomas et al. 1992). Coccinellids such as *H. convergens* can be attracted to a variety of flowering plants (Patt et al. 1997, Al-Doghairi and Cranshaw 1999). *Scarites* spp. have been found in high mowed (5-cm) turf (Terry et al. 1993, Braman et al. 2002). Hummel et al. (2002) found *Scarites* spp. to be less common in conventional tillage (low complexity, high disturbance) vegetable fields than in reduced tillage (higher complexity, lower disturbance) fields. These studies suggest it would be worthwhile to further investigate methods to attract *S. substriatus* and *P. lucublandus* to golf course roughs and fairways.

The exploration of what types and species of arthropods serve as alternative prey for predatory beetles and spiders has not been well explored, and this information is virtually missing from the turf literature. Research that has been conducted has examined the palatability of alternative prey items to predators in several agricultural systems. Collembola have been shown to be prey items for linyphiid spiders (Sunderland et al. 1986, Agustí et al. 2003) and carabid beetles (Bauer 1982, 1985; Bilde et al. 2000). Research has also demonstrated that carabid beetles will consume fly larvae in field experiments (Anthomyiidae: Coaker 1965, Grafius and Warner 1989; Chyronomidae and

others: Settle et al. 1996). Carabids also consume earthworms, slugs (Mair and Port 2001), and other nonpest arthropods (Best and Beegle 1977b). Staphylinid beetles were seen eating fly larvae by Coaker (1965). Similarly, in the feeding trials presented in this work, carabid and staphylinid species fed on all five alternative prey items tested. Positive correlations have been demonstrated between alternative prey (collembola) and carabid beetles (Potts and Vickerman 1974) and alternative prey (leafhoppers) and anyphaenid spiders (Shrewsbury 1996). These studies suggest that an abundance of palatable alternative prey may be useful in enhancing and retaining predator populations.

Other studies examining the palatability of alternative prey to predators have found not all prey to be palatable. One species of collembola, *Folsomia candida* (Willem), has been found to be toxic to certain carabid beetles (Bilde et al. 2000) and lycosid spiders (Toft and Wise 1999). Prey items such as these would obviously be of limited value to predators and perhaps should be left out of gross alternative prey estimates.

This experiment did not examine predators' preference for *A. ipsilon* and alternative prey types. Therefore, it cannot be determined what choices the predators would make if presented, in the field, with *A. ipsilon* larvae and alternative prey items. This interaction between predators, pests, and alternative prey has not received much attention. An abundance of alternative prey could result in greater consumption of pests or it could dilute the effect of predators on pests if the alternative prey are of higher quality or easier to catch. However, as a first step, this study provides fundamental knowledge of the palatability and vulnerability of insect pest species and potential alternative prey to predators, which is critical to developing and implementing conservation biological control programs. Identifying methods to increase the abundance of alternative prey that is palatable to voracious predators could result in increased predation of black cutworms and other golf course pests. This ultimately should lead to reduced pesticide inputs and their associated environmental and health risks.

## Acknowledgments

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